# Study of Plume Impingement Effects in the Lunar Lander Environment

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Plume impingement effects from the descent and ascent engine firings of the Lunar Lander were analyzed in support of the Lunar Architecture Team under the Constellation Program. The descent stage analysis was performed to obtain shear and pressure forces on the lunar surface as well as velocity and density profiles in the flow field in an effort to understand lunar soil erosion and ejected soil impact damage which was analyzed as part of a separate study. A CFD/DSMC decoupled methodology was used with the Bird continuum breakdown parameter to distinguish the continuum flow from the rarefied flow. The ascent stage analysis was performed to ascertain the forces and moments acting on the Lunar Lander Ascent Module due to the firing of the main engine on take-off. The Reacting and Multiphase Program (RAMP) method of characteristics (MOC) code was used to model the continuum region of the nozzle plume, and the Direct Simulation Monte Carlo (DSMC) Analysis Code (DAC) was used to model the impingement results in the rarefied region. The ascent module (AM) was analyzed for various pitch and yaw rotations and for various heights in relation to the descent module (DM).

For the ascent stage analysis, the plume inflow boundary was located near the nozzle exit plane in a region where the flow number density was large enough to make the DSMC solution computationally expensive. Therefore, a scaling coefficient was used to make the DSMC solution more computationally manageable. An analysis of the effectiveness of this scaling technique was performed by investigating various scaling parameters for a single height and rotation of the AM. Because the inflow boundary was near the nozzle exit plane, another analysis was performed investigating three different inflow contours to determine the effects of the flow expansion around the nozzle lip on the final plume impingement results.

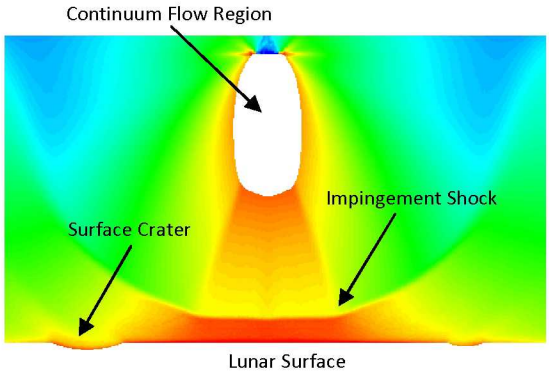


**Figure 1: Lunar Surface Impingement**

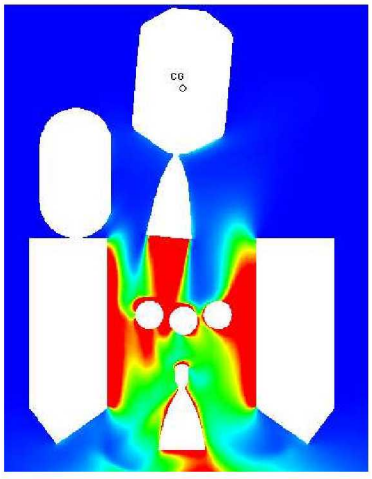

**Figure 2: Lunar Lander Ascent Module**